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Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

01200477.6

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

EUROPÄISCHES PATENTAMT DEN HAAG 237 OFFICE EUROPÉEN DES BREVETS LA HAYE

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LA HAYE, LE

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Application no.: 01200477.6
Demande n°:

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Date of filing: 12/02/01
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Koninklijke Philips Electronics N.V.
5621 BA Eindhoven
NETHERLANDS

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Titre de l'invention:
Magnetic head with a permanent-magnet layer structure

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

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Magnetic head with a permanent-magnet layer structure

The invention relates to a magnetic head including an at least substantially flat magnetic coil having at least one coil layer structure comprising an electrically conductive winding. The magnetic head is especially meant for use in a magneto-optical device.

An embodiment of such a magnetic head is disclosed in WO-A 98/48418. The magnetic head known from this PCT document includes a flat magnetic coil having two parallel coil sections, each coil section comprising a plurality of windings formed by means of a thin-film technology. The magnetic coil extends in a magnetic yoke which, with the coil, defines a central passageway for an optical beam. The known magnetic head is intended for use in a magneto-optical (MO) system for the storage of data in a magneto-optical (MO) medium comprising a recording layer, during recording or reading-out data the magnetic head being situated at a short distance from a main face of the MO medium. Such a magneto-optical system comprises apart from said magnetic head, a laser source and optical elements, which include a focusing lens, enabling a laser beam to be routed to a recording layer via the central passageway. During the storage of data the laser beam is utilized for reducing the coercivity of the recording layer of the MO medium in that selected spots are heated to approximately the Curie temperature of the recording layer. Meanwhile, the magnetic coil is activated to generate a time-varying magnetic field traversing the recording layer in order to define a pattern of magnetic domains. During reading-out stored information the MO medium is scanned with the laser beam, use being made of the magneto-optical Kerr effect, which is known per se.

During the magneto-optical storage of information the minimum width of the stored data bits is dictated by the diffraction limit, i.e. the numerical aperture (NA) of the focusing lens used and the wavelength of the laser beam sent out by the laser source.

A reduction of said width is generally based on shorter-wavelength lasers and higher-NA optical focusing systems. During magneto-optical recording the minimum bit length can be reduced to below the optical diffraction limit by using Laser Pulsed Magnetic Field Modulation (LP–MFM). In such a process the bit lengths are determined by the pulsing rate of the laser in combination with the alternating magnetic field. For reading-out the small marks recorded in this way use is made of magnetic super resolution (MSR) technologies,

including Domain Expansion methods, like MAMMOS based on media with magnetostatic coupled layers. An advantage of Domain Expansion methods is that marks with a length below the diffraction limit can be detected with a similar signal-to-noise ratio as marks with a size comparable to the diffraction limited spot.

In the IEEE Journal of Selected Topics in Quantum Electronics, Vol. 4, No. 5, September / October 1998, pages 815 – 820 a magnetic amplifying magneto-optical (MO) system, called MAMMOS, is described.

The concept of MAMMOS is to realize a signal enhancement by using magnetic-domain expansion at the readout time. Use is made of a storage medium comprising a storage layer and readout layer magneto-statically coupled to each other. During readout a laser beam heats the medium at the readout position. When a mark in the storage layer, i.e. a bit with a magnetization direction opposite to the initial magnetization direction of the readout layer, is within an area called, the copy window, where the temperature is high enough to enable magnetization reversal, a domain is nucleated in the readout layer. An external magnetic field is applied for expansion of this domain, after detection of the domain the field being reversed to collapse the domain.

The coil used in the magnetic head known from said WO-A 98/48418 has a limited readout resolution when applied in combination with MAMMOS.

It is an object of the invention to provide a magnetic head which increases the readout resolution by use of a Domain Expansion technology based on magnetostatic coupled layers.

This object is achieved with the magnetic head according to the invention, which magnetic head includes an at least substantially flat magnetic coil having at least one coil layer structure comprising an electrically conductive winding and further includes a permanent-magnetic layer structure extending substantially parallel to the coil layer structure and having an in-plane magnetic axis. Due to the applied measures the magnetic head according to the invention provides during use a time-varying perpendicular field generated by the coil layer structure and a static in-plane bias field generated by the permanent-magnetic layer structure. Suitable materials for the permanent-magnetic layer are e.g. CoPt or FePt alloys; Co/Pt or Co/Pd multilayers; $Nd_2Fe_{14}B$ or Co_5Sm rare earth transition metal compounds.

The nucleation of small reversed areas in the readout layer of a MAMMOS medium during an initial stage of the readout process mainly occurs in an area where the stray field is strongest and the stray field direction deviates from the perpendicular direction,

so the in-plane stray field component can exert a torque on the perpendicular magnetization in the readout layer to induce nucleation. During readout by means of known devices, nucleation will therefore not start adjacent to the center of a mark but adjacent to the mark/non-mark and non-mark/mark transitions. This leads to a broadening of the detection area and thereby to erroneously copied domains during high resolution readout.

By using the magnetic head according to the invention an external field with a magnetic field component in a track direction and of sufficient strength can be generated in order to suppress the disadvantageous effect of erroneously copied domains. The last-mentioned magnetic field component increases the nucleation of the mark/non-mark transition and decreases the nucleation of a non-mark/mark transition or vice versa depending on the direction of the in-plane field component. Combining the obtained tilted field with the copy window moving during readout leads to a reduced Bit Error Rate for small marks and non-marks. An effect of the structure in accordance with the invention is furthermore that an in-plan field component can enhance the initial domain expansion speed which is advantageous for high data rates. Apart from the above defined obtained effects the magnetic head according to the invention has the advantage that no current is required to generate the in-plane bias field so that heat dissipation can be kept limited.

To obtain high data rates during LP-MFM recording and MAMMOS readout or the like the magnetic coil should be small and close to the medium. Especially in a so-called First-Surface or Cover-Layer incident recording configuration where the coil and focussing optics are present at a same side of the magneto-optical medium and a laser spot is focussed through the coil the measures in accordance with the invention are advantageous. In this context an embodiment of the magnetic head according to the invention is characterized in that the magnetic coil has a central area and the conductive winding extends around this central area and in that the permanent-magnetic layer structure includes two flat permanent magnets located at opposite sides of the central area of the magnetic coil. The magnets have the same magnetization direction to generate the desired in-plane field in the central area of the magnetic coil. This embodiment offers the possibility to obtain a tilted field over a relatively large fraction of the central area of the coil during use without covering this central area. The central area may be a transparent inner area or an inner aperture. In case of Substrate incident recording where the magneto-optical medium extends between the coil and focussing optics and a laser beam does not pass the coil an embodiment in which the magnetic coil has a central area and the conductive winding extends around this area, the

permanent magnetic layer structure including a permanent magnet located in the central area, may be advantageous.

An embodiment of the magnetic head according to the invention which is able to generate a very high in-plane field in the medium is characterized in that the permanent-magnet layer structure is situated at a side of the coil layer structure which side is turned to a face of the head meant for positioning face to face with a main face of the storage medium. Said face of the head may be formed by or may include a head face extending at least partly parallel to the coil layer structure. The magnetic field generated by the configuration of this embodiment may increase near the edges of the permanent-magnet layer structure, however, this accidental effect hardly affects the readout process because the medium is not heated in the relevant region.

An alternative embodiment which does not have the above-described accidental effect is characterized in that the permanent-magnet coil structure is situated at a side of the coil structure which is turned away from the head face. This configuration in which the magnetic coil extends between the permanent-magnet layer structure and the head face may be preferred in spite of the possibly somewhat lower in-plane field.

A further alternative embodiment is characterized in that the permanent-magnetic layer structure and the coil layer structure are situated in a same plane, the coil layer structure extending between a pair of permanent magnets of the permanent-magnet layer structure. This embodiment is advantageous, in particular if the desired in-plane field component is required across a relatively vast area at a relatively large distance from the coil layer structure.

Depending on the dimensions of the central area of the magnetic coil and/or, during use, the distance of the coil to the medium, a soft magnetic layer structure extending substantially parallel to the coil layer structure can be advantageous in enhancing the field in the storage medium generated by the coil. For this reason an embodiment of the magnetic head according to the invention is provided with such a soft magnetic layer structure. In such an embodiment the coil layer structure may extend between the permanent-magnet layer structure and the soft magnetic layer structure or the soft magnetic layer structure may be situated at a side of the coil layer structure which side is turned away form the head face. The soft magnetic layer structure improves the efficiency of the conductive winding. Moreover, in particular if the permanent-magnet layer structure and the coil layer structure are situated in the same plane, the efficiency of the permanent magnets is improved by the soft magnetic layer structure. The soft magnetic layer structure may be a continuous soft film in case of a

recording configuration where the magnetic coil is situated at one side of the medium and the laser beam is focussed through the substrate of the storage medium to a spot. Otherwise, the soft magnetic layer structure may be formed as an interrupted soft magnetic film. Suitable soft magnetic materials for the soft magnetic layer structure are e.g. NiFe or CoZrNb or FeTaN alloys.

A solid metallic permanent-magnet film as the permanent-magnet layer structure may give rise to eddy currents which may be induced when the coil is operated at high frequencies. An embodiment of the magnetic head according to the invention in which the generation of eddy currents is minimized is characterized in that the permanent-magnet layer structure is a laminated layer-structure having at least one electrically non-conductive intermediate layer. The magnetic material may be e.g. a CoPt alloy and the insulation material may be e.g. SiO_2. Eddy currents as well as a capacitive coupling of the magnetic coil with the permanent-magnet layer structure may also be counteracted by configuring the permanent-magnet layer structure in the form of small magnetic stripes alternating with non-magnetic small stripes instead of one magnetic film, thus resulting in a structure having a stripy pattern.

The invention further relates to a slider for use in a magneto-optical device. The slider according to the invention includes the magnetic head according to the invention. The slider has preferably the features as defined in Claim 12.

Furthermore, the invention relates to an optical recording and/or reproducing head having an objective provided with the magnetic head according to the invention. The objective which serves for focusing and/or tracking, may be moved by actuating means known per se.

The invention also relates to a magneto-optical device, the device including the magnetic head according to the invention or the slider according to the invention or the optical head according to the invention.

To conclude, the invention relates to a method of reading out information present in a track of a magneto-optical medium having magneto-statically coupled or exchange coupled layers including a storage layer and a readout layer. During carrying out the method a laser beam focussed to a spot in the readout layer and an external magnetic field are applied. The method according to the invention is characterized in that use is made of a permanent magnet for generating a magnetic field component in the medium, particularly in the readout layer, in a direction of the track. The method according to the invention is based on the same insight as previously explained. Preferably the magnetic head according to the

invention or the slider according to the invention or the optical head according to the invention is used for carrying out the method.

With reference to the Claims, it is to be noted that various characteristic features as defined in the set of Claims may occur in combination. The above mentioned and other aspects of the invention are apparent from and will be elucidated, by way of non-limitative example, with reference to the embodiments described hereinafter.

In the drawings:

Figure 1 is a diagrammic plan view which shows the principle of the magnetic head in accordance with the invention and meant for use in a magneto-optical device,

Figure 2 is a graph which represents the flux lines in a cross section, similar to the cross section indicated by X-X in Figure 1, of an embodiment of the magnetic head in accordance with the invention,

Figures 3 to 7 diagrammatically show several embodiments of the magnetic head or the slider in accordance with the invention in sectional views similar to the sectional view taken on the line X-X in Figure 1,

Figure 7A diagrammatically shows a cross section in accordance with the line VIIA-VIIA through the embodiment of Figure 7,

Figure 7B diagrammatically shows a plan view in accordance with the arrow VIIB in Figure 7,

Figure 8 diagrammatically shows an application of the magnetic head in accordance with the invention, and

Figure 9 diagrammatically shows a cross-section of an optical head in accordance with the invention.

The component diagrammatically shown in Figure 1 is meant for use in a magneto-optical device, in particular a device by means of which MAMMOS readout can be carried out. The component is formed by a magnetic head in accordance with the invention. The component includes an at least substantially flat magnetic coil 1 having at least one coil layer structure which structure comprises an electrically conductive winding. In this example the coil 1 has two coil layer structures 3a and 3b each comprising a conductive winding 5a and 5b, respectively. Each of the windings 5a and 5b has a connecting surface 6a and 6b, respectively, the windings being electrically interconnected by an interconnection 6c. The material of the windings may be a metal, like Cu or Au. The component further includes a

permanent-magnet layer structure 7, which extends substantially parallel to the coil layer structures 3a and 3b and has an in-plane magnetic axis m. The magnetic coil 1 has a middle or central area 10, the conductive windings 5a and 5b extending around the central area 10. The area 10 may be transparent. The permanent-magnet layer structure 7 includes two flat permanent magnets 9a and 9b located at opposite sides of the central area 10 of the magnetic coil 1. The two magnets 9a and 9b have the same magnetization direction M to generate an in-plane magnetic field in the central area 10 of the coil 1. The permanent-magnet may be formed of e.g. a CoPt alloy. A desired tilting angle of the flux lines for MAMMOS readout can be attained by optimizing the position and/or dimensions and/or the composition of the magnets 9a and 9b, e.g. by changing the distance between the magnets, varying their thickness, varying the permanent-magnet material.

Figure 2 shows the flux lines in a cross section of a typical configuration during use and indicates that a tilting of the field by about 45 degrees can be obtained in the central area of the magnetic coil. The coil 101 used in this configuration is a so-called dual-layer magnetic coil, thus having two coil layer structures 103a and 103b, which each comprises an electrically conductive winding 105a and 105b, respectively. The coil 101 has a coil axis 101a. Apart from the coil 101 the configuration includes a permanent-magnet layer 107 including two flat permanent magnets 109a and 109b located at opposite sides of the central area, here indicated by 110, which magnets have the same magnetization direction M. The permanent-magnet layer 107 has in this example a thickness of 3μm and is formed of a CoPt alloy. The distance between the two magnets 109a and 109b is about 90μm. It is possible to obtain a magnitude of the magnetic field of at least 15 kA/m in the central area and it has been proved that such a magnitude is sufficient for MAMMOS readout.

The embodiment shown in Figure 3A which is a slider in accordance with the invention - but may be a magnetic head in accordance to the invention - includes a coil layer structure 203 comprising an electrically conductive winding 205 and further includes a permanent-magnet layer structure 207 comprising two flat permanent magnets 209a and 209b located at opposite sides of a central area 210. The embodiment has a slider-body 218 provided with a face 220, in this document also mentioned head face, which is meant to be positioned, during use, opposite to a main face of a magneto-optical storage medium. In this example the permanent-magnet layer structure 207 is situated at a side of the coil layer structure 203 which is turned to the head face 220. In other words the permanent layer structure extends between the coil layer structure and the head face. It will be clear that in this embodiment a slider and a magnetic head form an integral unit or component. The

embodiment shown in Figure 3B includes a permanent-magnet layer structure 207 which extends parallel to a coil layer structure 203 at a side thereof which is turned away from a head face 220. The embodiment shown in Figure 3C includes a permanent layer structure 207, which is present in a central area 210 of a coil layer structure 203.

The embodiment shown in Figure 4 includes a coil layer structure 303, a permanent-magnet layer structure 307 and a soft magnetic layer structure 330, including two soft magnetic layer portions 331a and 331b in order to make it possible to create a transparent central area 310. This is required if a laser-beam is led through the magnetic coil during a recording and/or readout process. All these layer structures are parallel to each other, the coil layer structure 303 extending between the layer structures 307 and 330. The soft-magnetic layer structure 330 is situated at a side of the coil layer structure 303 which is turned away from a head face 320. The soft-magnetic layer structure may be formed of e.g. a NiFe alloy.

The embodiment shown in Figure 5 has a head face 420 and includes a coil layer structure 403 and a permanent-magnetic layer structure 407 both lying in one and the same plane extending parallel to the head face 420. The permanent-magnet layer structure 407 has at least one pair of magnets 409a and 409b, the structure 407 extending between the magnets 409a and 409b.

The embodiment shown in Figure 6 resemblances the embodiment of Figure 5, but is additionally provided with a soft-magnetic layer structure 530 extending parallel to a head face 520 and being such arranged that a coil layer structure 503 and a permanent-magnet layer structure 507 extend between on the one side a soft-magnet layer structure 530 and on the other side the head face 520.

The embodiment shown in the Figures 7, 7A and 7B includes a coil layer structure 603 and a permanent-magnet layer structure 607 mutually extending parallel. In order to prevent eddy currents in the permanent-magnet layer structure 607 this layer is laminated in such a way that sublayers 640 of a permanent-magnetic material, such as e.g. a CoPt alloy, alternate with intermediate layers 642 of a non-conducting material, such as e.g. quartz.

The embodiment of the magneto-optical device in accordance with the invention shown in Figure 8 has a frame 751 which rotably supports a spindle 753 for a magneto-optical (MO) disc 755 and has two magnetic yokes 757 of a slide drive secured to it. The slide drive further includes two drive coils 759a which cooperate with the magnetic yokes. The drive coils 759a form parts of a slide 759 capable of performing radial translational movements with respect to the spindle 753. The slide 759 has a spring

suspension 761, which carries an embodiment 763 of the slider in accordance with the invention, e.g. the slider shown in Figure 3. The device shown in Figure 8 can be used for carrying out the method of reading out in accordance with the invention. According to this method information present in a track of a magneto-optical storage medium having magnetostatically coupled layers is read out by application of a laser spot and an external magnetic field, a permanent magnet, particularly formed by said permanent-magnetic layer structure, being applied for generating a magnetic field component in the storage medium in a direction of the track. In this way, in which a planar magnetic field modulation coil in combination with a structured permanent-magnet layer is used, a high-resolution and low bit-error-rate MAMMOS readout is attained.

The embodiment of the optical recording and/or reproducing head shown in Figure 9 may be a part of a magneto-optical apparatus and is provided with an objective including an objective lens 802a and a front lens 802b. The objective 802a, 802b is fixed in a frame 804 having a support 806 for an actuator element of a focus and/or tracking actuator. The objective, particularly the front lens 802b thereof, is provided with an embodiment 808 of the magnetic head according to the invention, e.g. the magnetic head shown in Figure 7. By means of said actuator the front lens 802b with the magnetic head 808 is able to make focus movements F and/or tracking movements T with respect to a MO disc 810.

It is to be noted that the invention is not limited to the examples shown herein. Thus, the magnetic coil may have more than one or two coil layers, or coil layer structures. Moreover, it is possible to use a magnetic head in accordance with the invention secured to or mounted on a slider, instead of a magnetic head integrated in the slider. Furthermore, the MO device can be provided with a swingable arm instead of or additional to a slide.

It is further noted that the measures as defined in this patent document can be advantageously combined with the measures disclosed in the European Patent Application with application number 00201412.4 (PHNL000221 EPP; herewith incorporated by reference). This means that the flat magnetic coil may have parallel coil layers each of the coil layers having a turn arranged around the central area of the coil. At least one of the coil layers may have turns of which the turns closer to the central area have smaller widths than the turns further away from the central area, while at least one of the coil layers has an outermost turn situated closer to the central area than the outermost turn of one of the other coil layers. Such a coil structure has a limited capacitance while the power dissipation is also limited.

 EPO - DG 1 09.02.2001

CLAIMS: 12 02 2001

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1. A magnetic head, particularly meant for use in a magneto-optical device, which head includes an at least substantially flat magnetic coil having at least one coil layer structure comprising an electrical conductive winding, and further includes a permanent-magnet layer structure extending substantially parallel to the coil layer structure and having an in-plane magnetic axis.

2. A magnetic head as claimed in Claim 1, the magnetic coil having a central area and the conductive winding extending around the central area, wherein the permanent-magnet layer structure includes two flat permanent magnets located at opposite sides of the central area of the magnetic coil.

3. A magnetic head as claimed in Claim 1, the magnetic coil having a central area and the conductive winding extending around the central area, wherein the permanent-magnet layer structure includes a permanent magnet located in the central area.

4. A magnetic head as claimed in Claim 1 and provided with a head face extending at least partly parallel to the coil layer structure, wherein the permanent-magnet layer structure is situated at a side of the coil layer structure which side is turned away from the head face.

5. A magnetic head as defined in Claim 1 and provided with a head face extending at least partly parallel to the coil layer structure, wherein the permanent-magnet layer structure is situated at a side of the coil structure which is turned to the head face.

6. A magnetic head as defined in Claim 1 and provided with a head face extending at least partly parallel to the coil structure, wherein the permanent-magnet layer structure and the coil layer structure are situated in a same plane, the coil layer structure extending between at least two permanent magnets of the permanent-magnet layer structure.

7. A magnetic head as claimed in Claim 1, including a soft magnetic layer structure extending substantially parallel to the coil layer structure.

8. A magnetic head as claimed in Claim 7, wherein the coil layer structure extends between the permanent-magnet layer structure and the soft magnetic layer structure.

9. A magnetic head as claimed in Claim 8 and provided with a head face extending at least partly parallel to the coil layer structure, wherein the soft magnetic layer structure is situated at a side of the coil layer structure which side is turned away from the head face.

10. A magnetic head as claimed in Claim 1, wherein the permanent-magnet layer structure is a laminated layer structure having at least one electrically non-conductive intermediate layer.

11. A slider for use in a magneto-optical device and including the magnetic head as claimed in any one of the preceding Claims.

12. A slider as claimed in Claim 11, having a slider-body with which the magnetic head is integrated.

13. An optical recording and/or reproducing head having an objective provided with the magnetic head as claimed in anyone of the Claims 1 to 10.

14. A magneto-optical device including the magnetic head as claimed in any one of the Claims 1 through 10, or including the slider as claimed in Claim 11 or 12, or including the optical head as claimed in Claim 13.

15. A method of reading out information present in a track of a magneto-optical storage medium having magnetostatically coupled or exchange coupled layers by application of a laser spot and an external magnetic field, wherein use is made of a permanent magnet for generating a magnetic field component in said medium in a direction of the track.

16. A method as claimed in Claim 15, wherein use is made of the magneto-optical device as claimed in Claim 14.

ABSTRACT:

For high-resolution and low bit-error-rate MAMMOS readout a magnetic head is proposed which includes a flat magnetic coil (1) having a coil layer structure (3a, 3b) comprising an electrically conductive winding (5a, 5b) and which includes a permanent-magnet layer structure (7) extending parallel to the coil layer structure and having an in-plane magnetic axis (m).

(Fig. 1)

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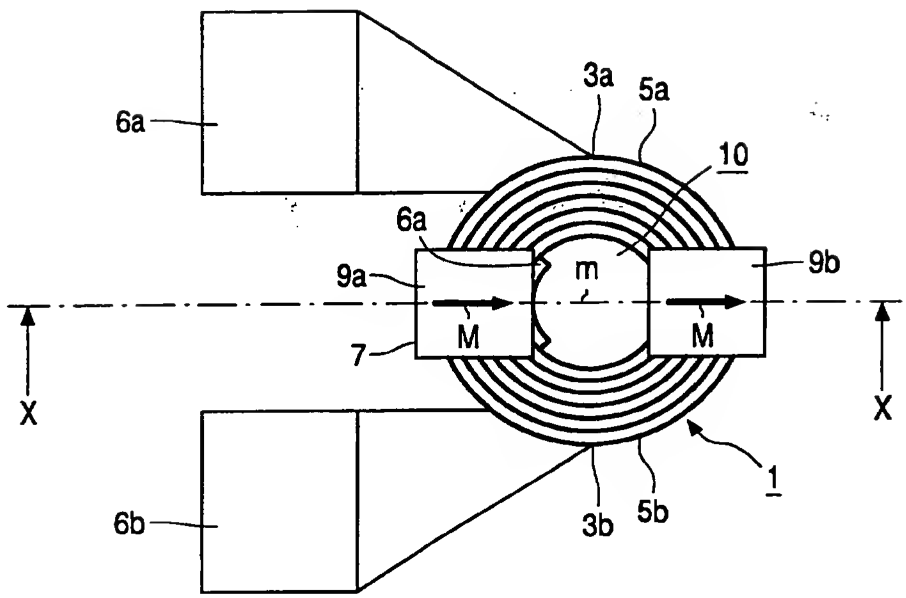

FIG. 1

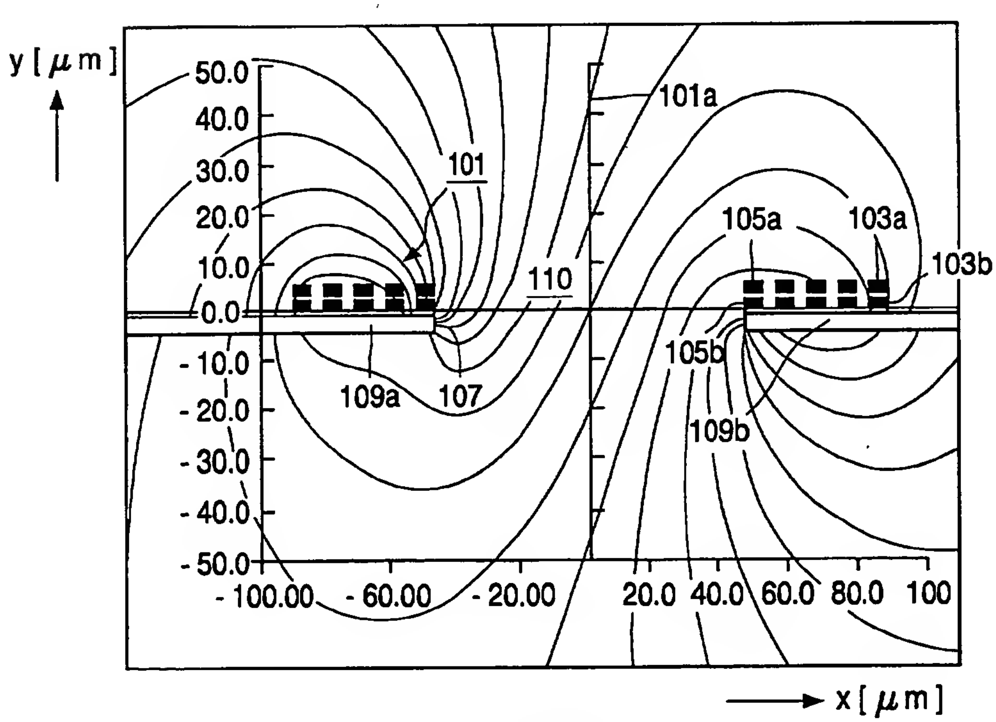

FIG. 2

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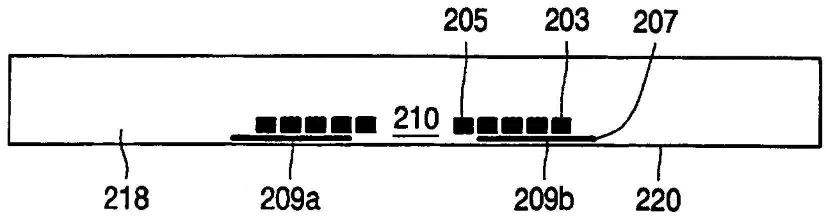

FIG. 3A

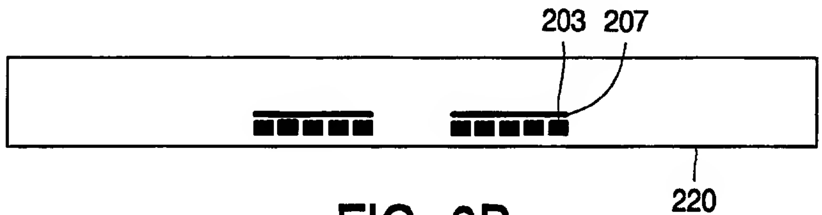

FIG. 3B

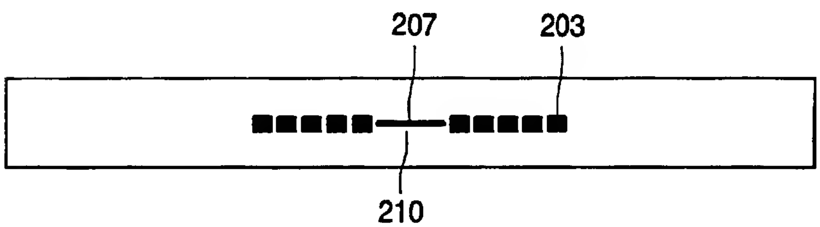

FIG. 3C

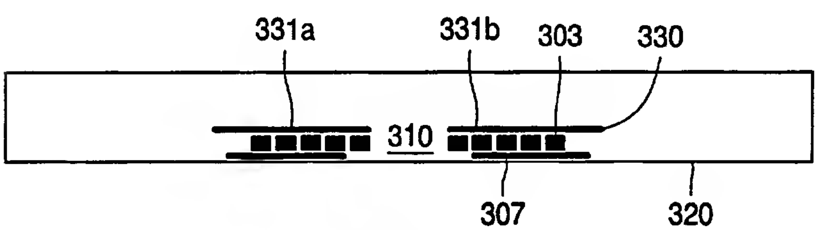

FIG. 4

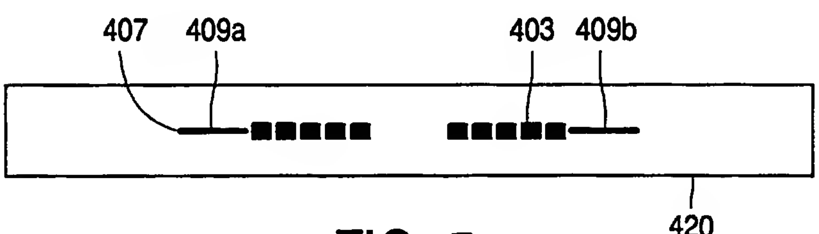

FIG. 5

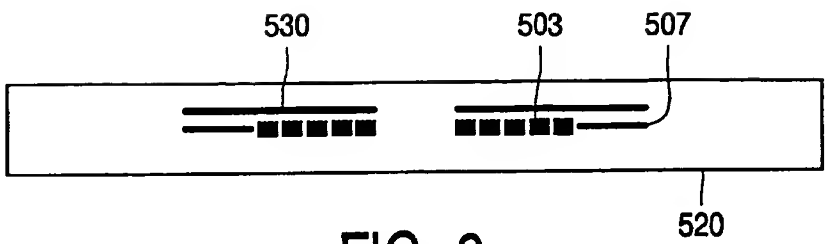

FIG. 6

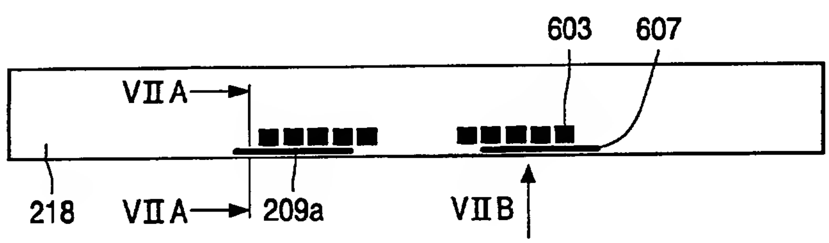

FIG. 7

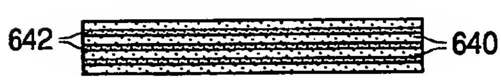

FIG. 7A

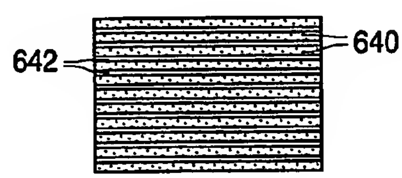

FIG. 7B

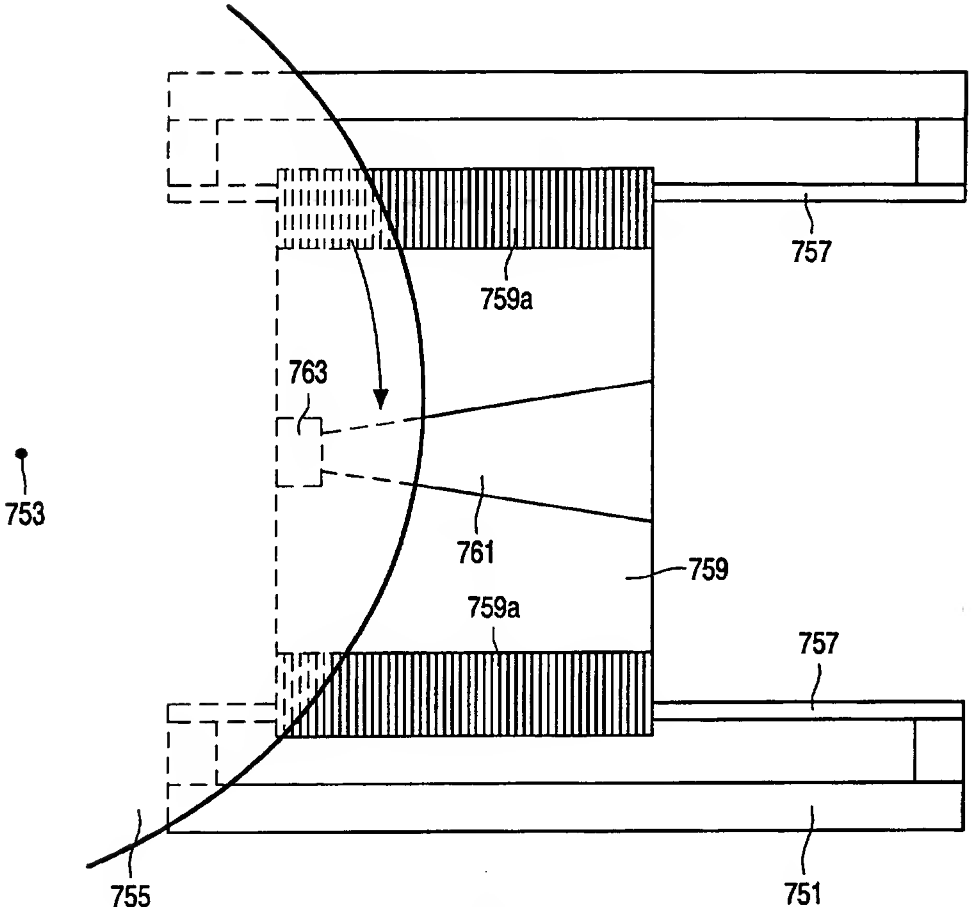
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FIG. 8

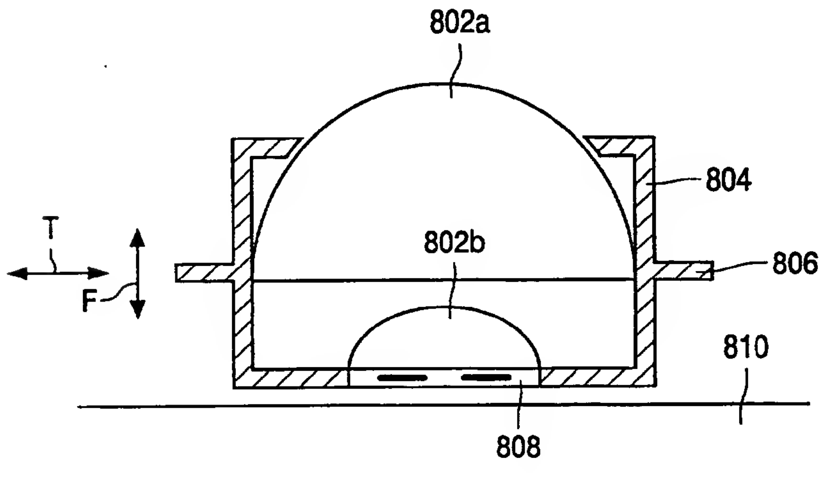
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FIG. 9